Hydrol. Earth Syst. Sci. Discuss., 11, C6400–C6403, 2015
www.hydrol-earth-syst-sci-discuss.net/11/C6400/2015/

Hydrology and Earth System Sciences
Discussions
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Interactive comment on "From runoff to rainfall: inverse rainfall–runoff modelling in a high temporal resolution" *by* M. Herrnegger et al.

Anonymous Referee #3

Received and published: 6 February 2015

General comments:

This manuscript claims that one can use a calibrated rainfall-runoff model to "predict" rainfall from runoff time series, by using a search algorithm to find, hour by hour, the rainfall rate that best fits the observed runoff.

This result is somewhat surprising, because mathematically speaking one would expect the inversion of a multi-compartment model to be ill-posed (because different rainfall inputs at different times, and different combinations of storage levels in the different compartments, should lead to the same discharge), and possibly also mathematically unstable. In that respect the results claimed here are intriguing.

However, the manuscript does not make a convincing case for its central claims, in

several important respects.

1. First of all, the manuscript claims to "predict" rainfall from runoff, but it can only do this at sites where it already has extensive rainfall data to calibrate the model with. This leaves the reader wondering: how can we "predict' a rainfall time series if, in order to do so, we must already *have* the rainfall time series so that we can calibrate the model?

2. The manuscript claims that this method will be useful for generating improved estimates of mean areal rainfall. The manuscript presents no convincing evidence to support this claim. Indeed, unless one already *has* good estimates of mean areal rainfall, one will be calibrating the model with incorrect rainfall data, with potentially serious consequences for the calibrated parameter values and the resulting "predictions" of rainfall from runoff.

3. This is a 12-parameter model. More than two decades ago, Jakeman and Hornberger (1993) showed that typical rainfall-runoff time series were unable to constrain the parameters of even a two-compartment, four-parameter hydrologic model. A 12-dimensional parameter space is absolutely vast compared to a four-dimensional parameter space (as a simple illustration, a 4-dimensional cube has 16 corners, but a 12-dimensional cube has 4096 corners). Rampant equifinality is virtually guaranteed in such a model. The manuscript gives no indication of any awareness of the equifinality problem, and no indication that anything has been done to deal with it, or even to assess how serious it is.

4. The only validation that is presented here consists of calibrating the model for 2006, 2007, and 2008, and then running it without calibration in 2009. It should be recognized that this is an extremely weak test, because the model is being tested against one year that is nearly identical to the three other years that it was already calibrated with (at least I believe this to be the case, but the figures present almost no information about the validation data, whereas the calibration data are presented in much greater

detail). This problem was already pointed out over a decade ago by Seibert (Nordic Hydrology 34, 477-492, 2003) in the context of rainfall-runoff modeling. Seibert observed that models typically give good fits to calibration data, and also to "validation" data that is virtually the same as the calibration data, but then fail spectacularly whenever they are tested against data that are somewhat outside the calibration conditions (that is, whenever the "predictions" are really predictions, rather than fits to existing data or functionally equivalent data sets). This problem becomes more acute as models become more parameterized; thus it is likely to be a particularly serious problem in the present case. The manuscript must demonstrate that the proposed approach can predict rainfall under conditions that are substantially different from the conditions the model has already been calibrated against.

5. The abstract claims that "To verify the existence, uniqueness and stability of the inverse rainfall, numerical experiments with synthetic hydrographs as inputs into the inverse model are carried out successfully." Absolutely no evidence to support this statement is provided; the reader is referred instead to the first author's Ph.D. thesis. What was done, apparently, was to put precipitation numbers into the forward model to generate streamflow, then to put exactly those streamflow numbers into the inverse model to generate precipitation again. This does not demonstrate stability, at least in any sense that really matters. It does not test, for example, whether small errors in the streamflow numbers will generate big errors in the inferred precipitation (which would seem to be likely, particularly at short time scales). It also does not test the even more important question of how structural errors in the model (which must exist, because no model is an exact copy of the real hydrological system) will affect the accuracy of the rainfall "predictions".

5. Figures 10 and 16 show impressive-looking cumulative rainfall curves, which appear to show very close correspondence between the model results and two data sets. It is important to recognize that this proves nothing except that the model conserves mass, and thus that the amount of rainfall that is predicted to go into the model is consistent

with the runoff that is measured going out of it (plus evapotranspiration, about which surprisingly little is said).

6. At a shorter time scale, the same effect is likely to be behind the apparent increase in goodness-of-fit, shown in Figure 11, as rainfall estimates are averaged over longer intervals, from 1 hour to 6 hours to 24 hours. Because the model must conserve mass, the integrated inputs and outputs must be equal, over timescales than the storm response timescale (that is, the timescale that changes in storage can allow inputs and outputs to diverge substantially). Thus as the averaging interval becomes longer, the inputs and outputs must match more closely.

7. In this respect, it is interesting to compare the results presented in Figure 11 with the much simpler method of Kirchner (2009). In the current manuscript, the inverse model predicts one-hour precipitation with an r-squared of 0.24, whereas Table 4 of Kirchner (2009) shows r-squared values of 0.66 (r=0.81) and 0.77 (r=0.88) for one-hour rainfall predictions at his two sites. Most importantly, in that approach, predictions are really predictions, because they are not calibrated against any precipitation measurements.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 13259, 2014.